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**Chien et al.**

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(54) **MOBILE DEVICE**

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(51) **Int. Cl.**

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| ***H01Q 1/38*** | (2006.01) |
| ***H01Q 1/06*** | (2006.01) |
| ***H01Q 13/10*** | (2006.01) |
| ***H01Q 9/42*** | (2006.01) |
| ***H01Q 21/30*** | (2006.01) |

(52) **U.S. Cl.**

CPC ..... ***H01Q 9/42*** (2013.01); ***H01Q 13/10*** (2013.01); ***H01Q 21/30*** (2013.01); *H01Q 1/243* (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 21/30; H01Q 5/0058; H01Q 5/357; H01Q 5/371; H01Q 1/243

USPC ..... 343/700 MS, 721

See application file for complete search history.

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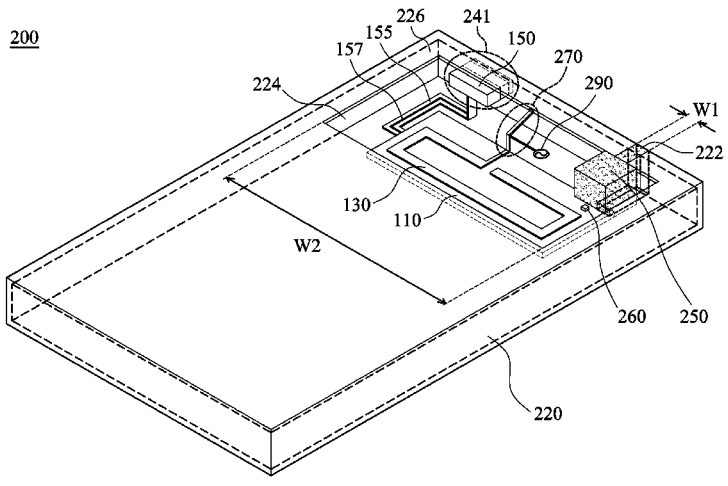
(57) **ABSTRACT**

A mobile device includes a substrate, a ground element, and a radiation branch. The ground element includes a ground branch, wherein an edge of the ground element has a notch extending into an interior of the ground element so as to form a slot region, and the ground branch partially surrounds the slot region. The radiation branch is substantially inside the slot region, and is coupled to the ground branch of the ground element. The ground branch and the radiation branch form an antenna structure.

**17 Claims, 8 Drawing Sheets**



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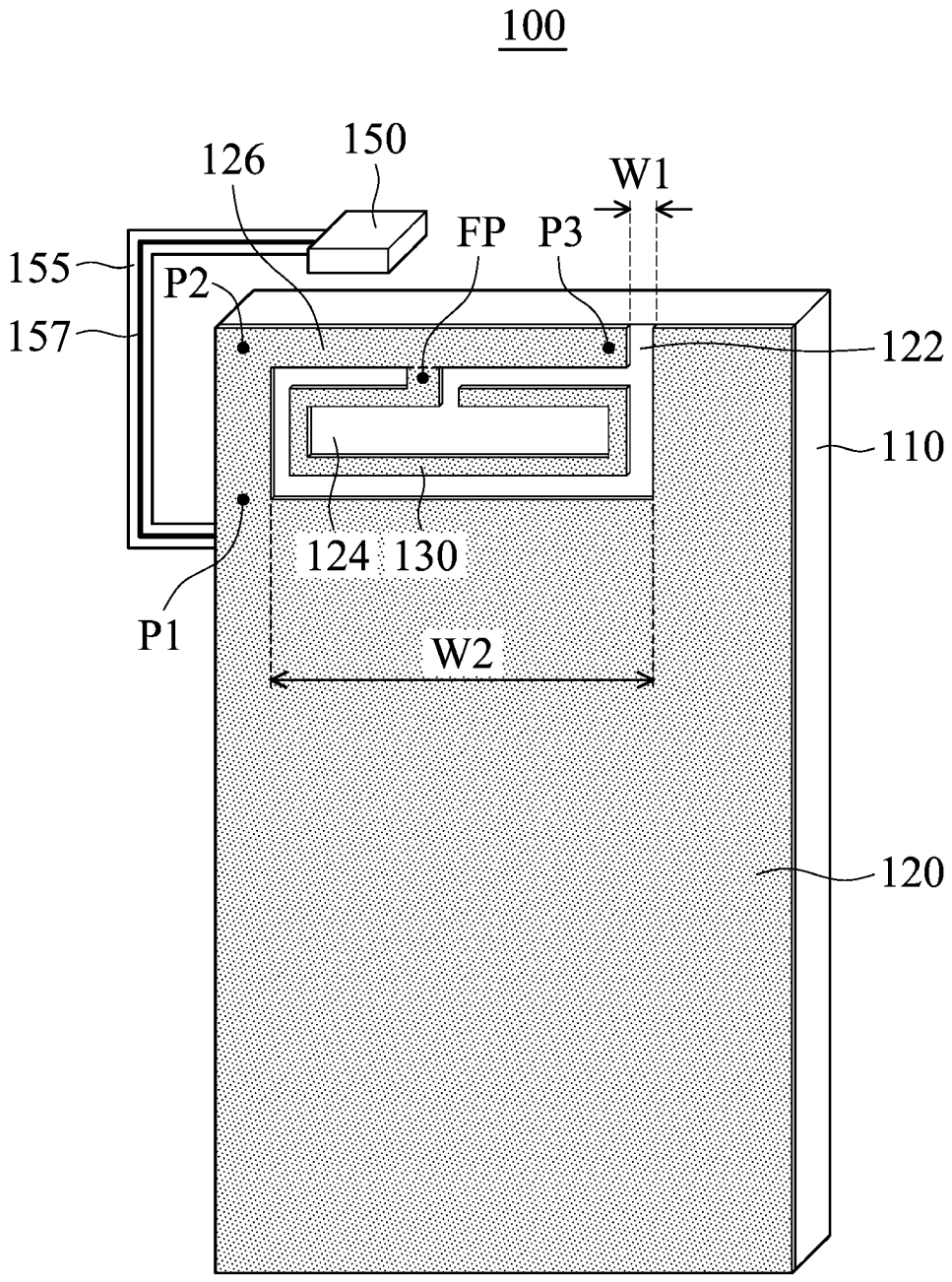


FIG. 1

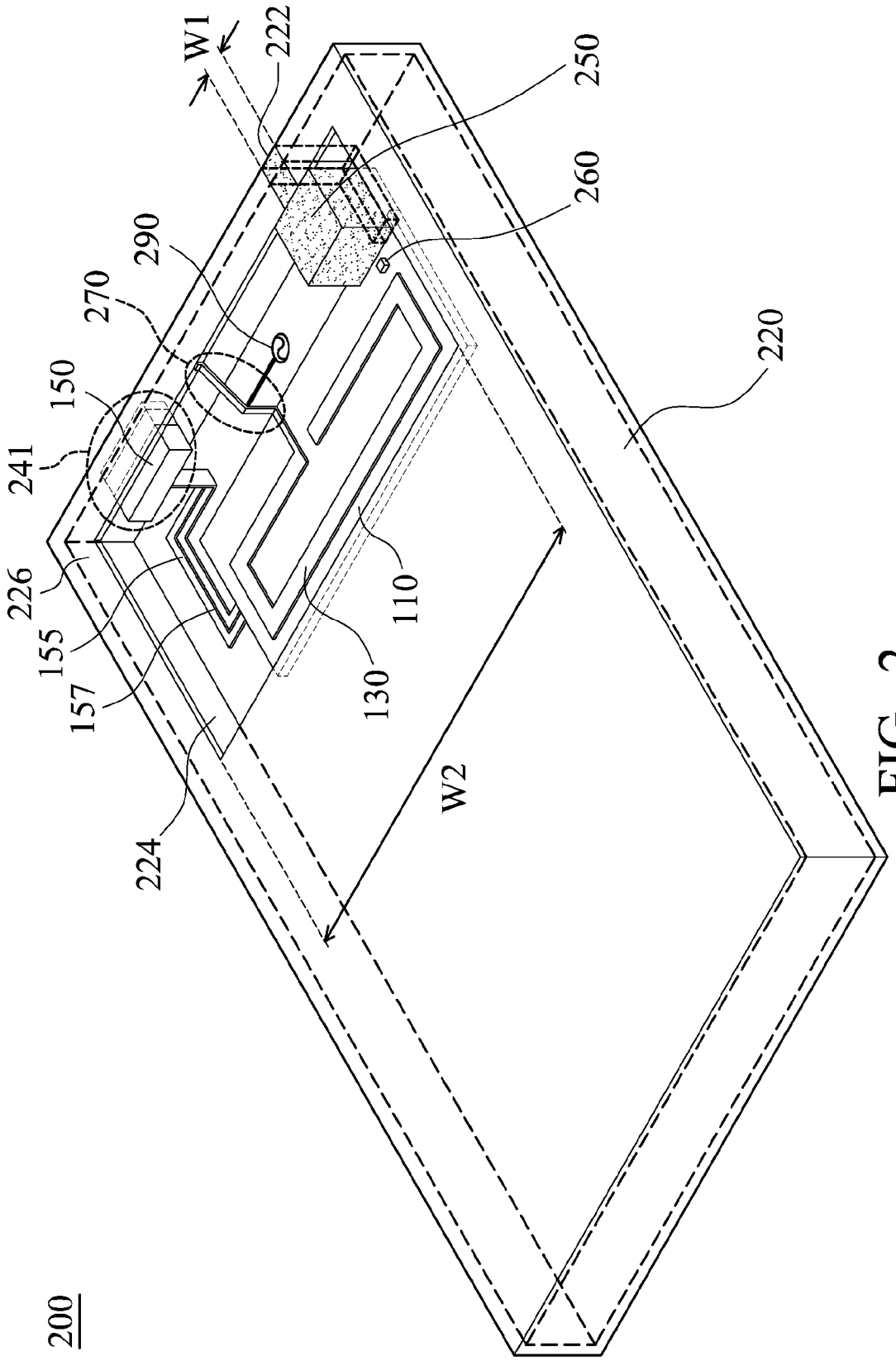


FIG. 2

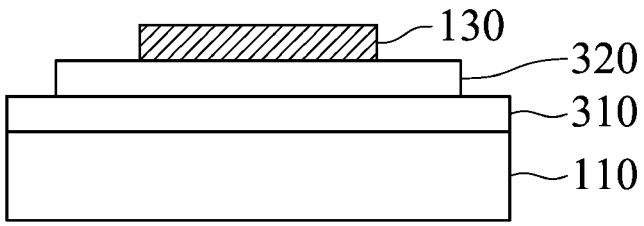


FIG. 3

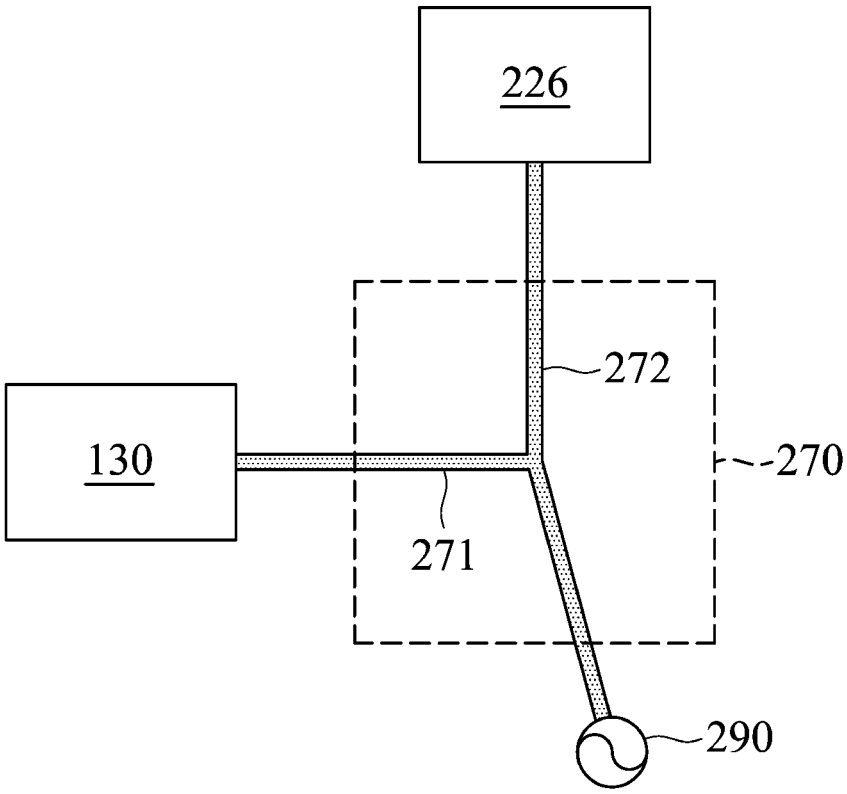


FIG. 4

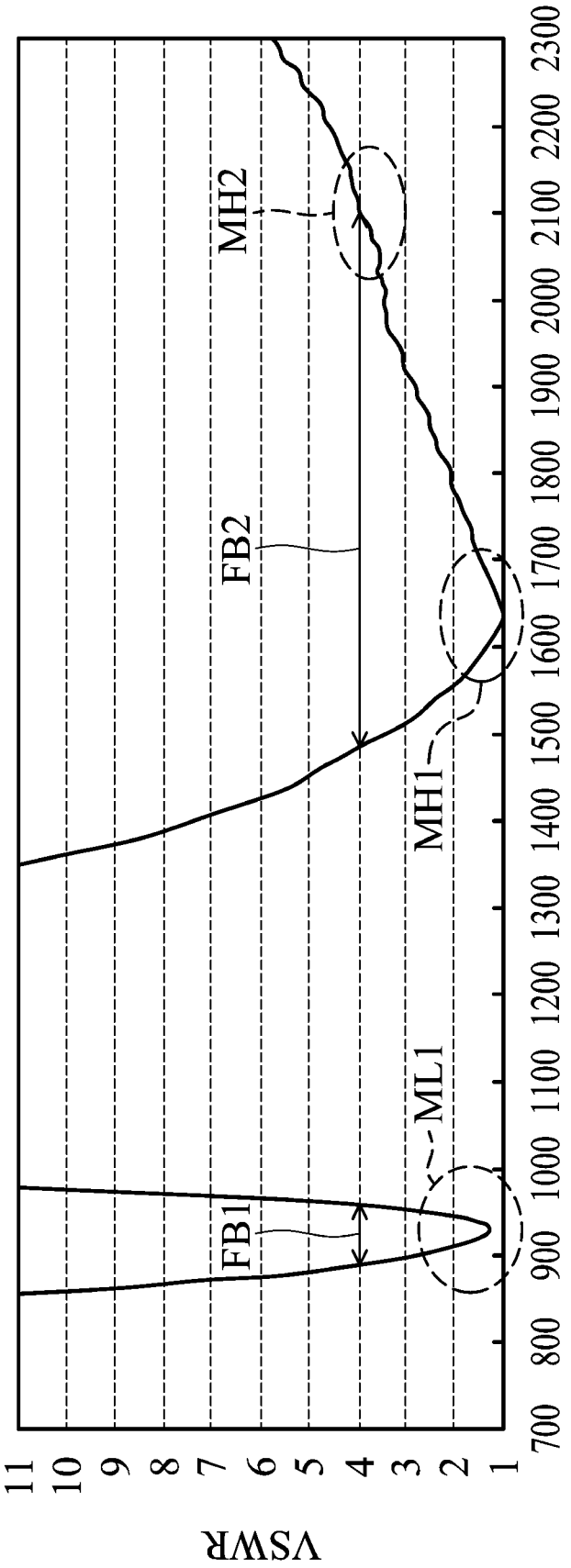
VSWR
11
10
9
8
7
6
5
4
3
2
1
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
Frequency (MHz)
FB1
FB2
ML1
MH1
MH2

FIG. 5

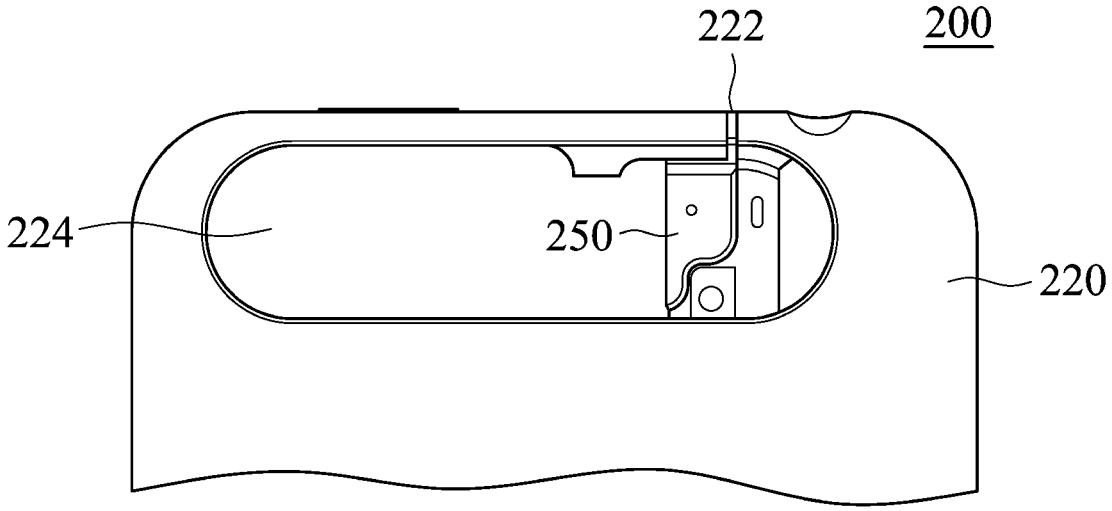


FIG. 6A

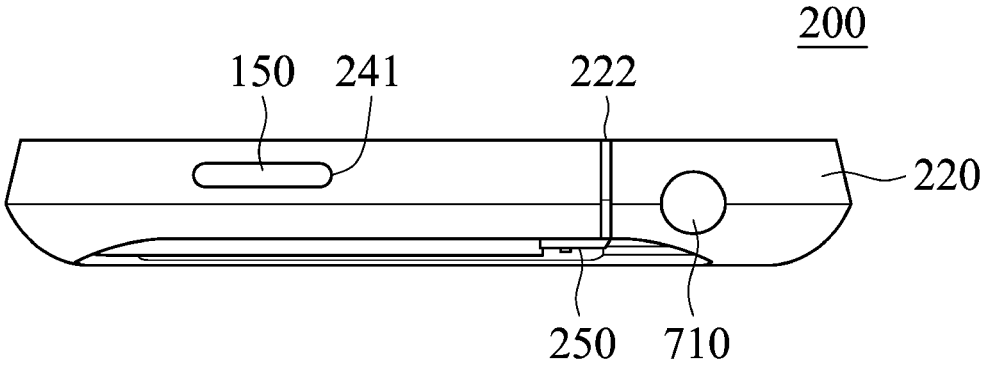


FIG. 6B

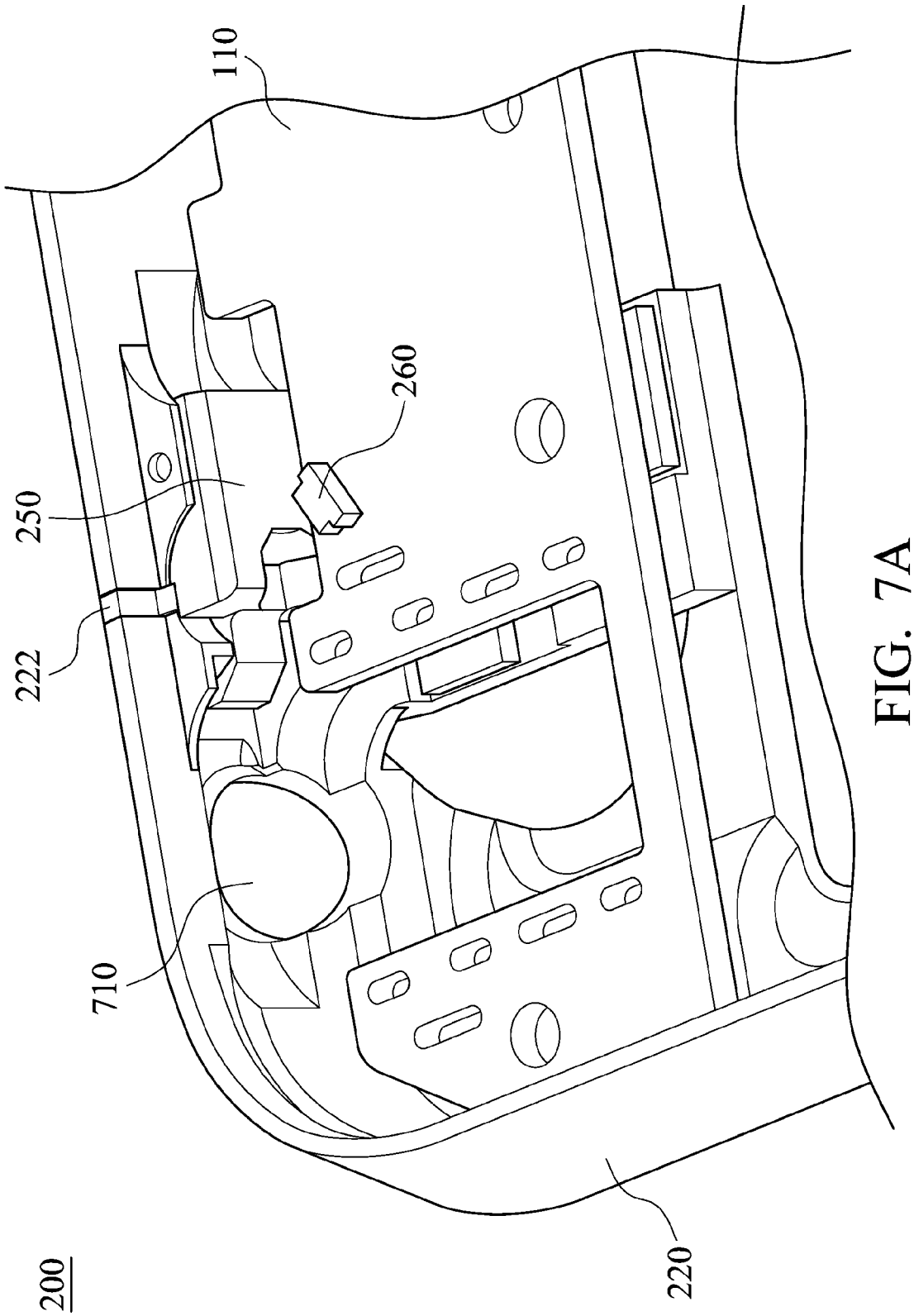


FIG. 7A

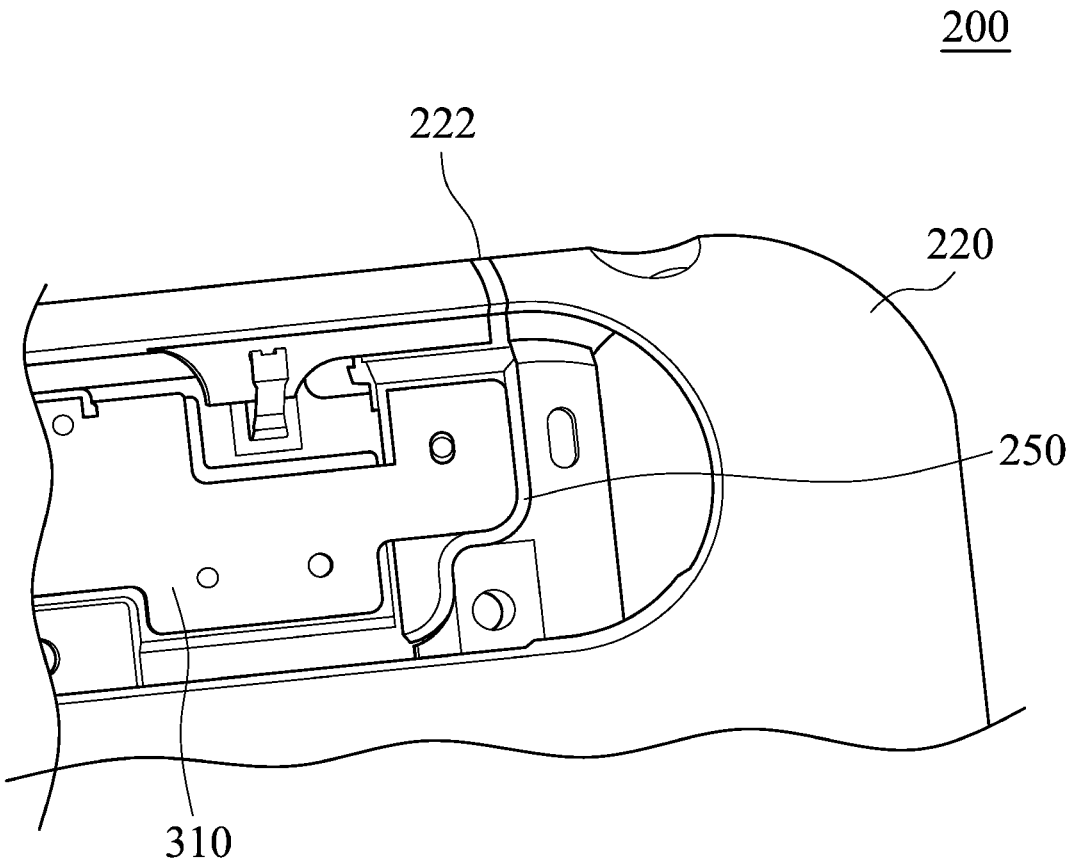


FIG. 7B

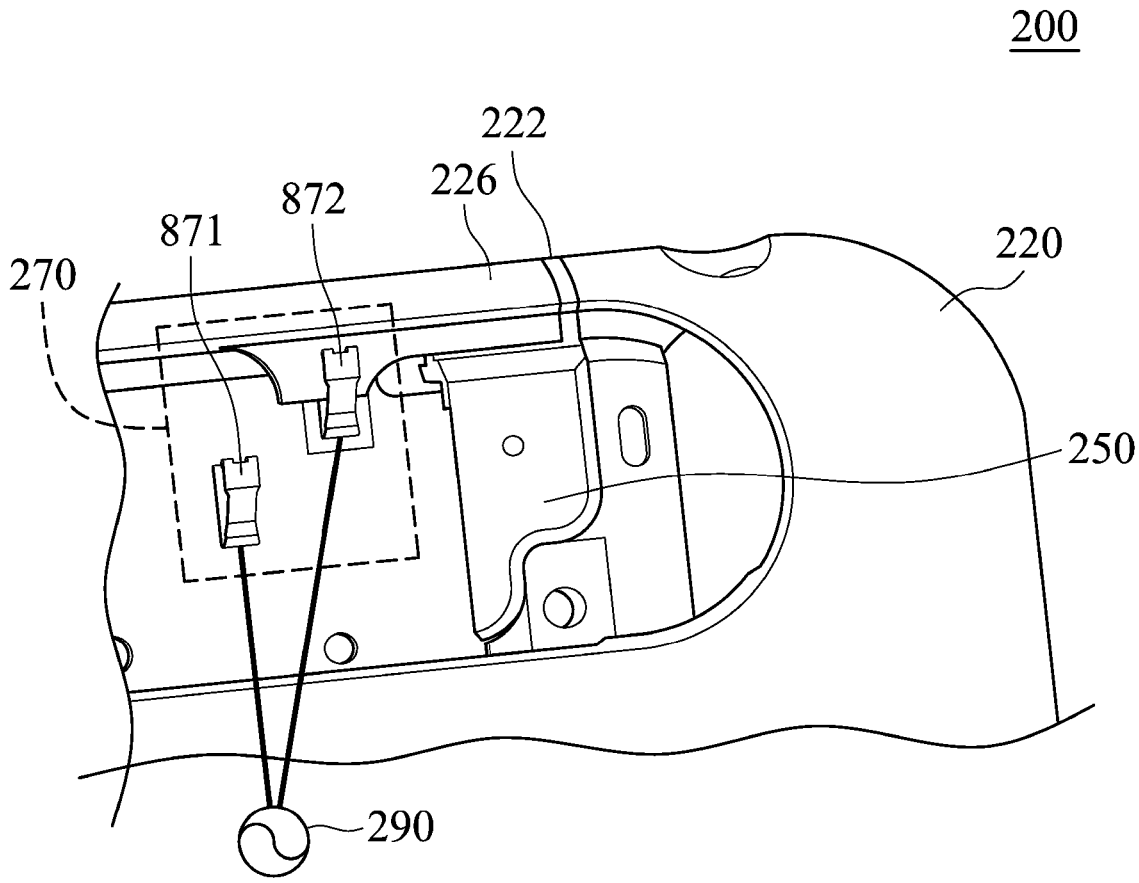


FIG. 7C

# MOBILE DEVICE

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The subject application generally relates to a mobile device, and more particularly, relates to a mobile device for operation in multiple frequency bands.

2. Description of the Related Art

With the progress of mobile communication technology, portable electronic devices, for example, portable computers, mobile phones, multimedia players, and other hybrid functional portable electronic devices, have become more common. To satisfy the demand of users, portable electronic devices usually can perform wireless communication functions. Some functions cover a large wireless communication area, for example, mobile phones using 2G, 3G, GPS and LTE (Long Term Evolution) systems and using frequency bands of 700 MHz, 850 MHz, 900 MHz, 1800 MHz, 1575 MHz, 1900 MHz, 2100 MHz, 2300 MHz, and 2500 MHz. Some functions cover a small wireless communication area, for example, mobile phones using Wi-Fi, Bluetooth, and WiMAX (Worldwide Interoperability for Microwave Access) systems and using frequency bands of 2.4 GHz, 3.5 GHz, 5.2 GHz, and 5.8 GHz.

Traditionally, a metal element with a fixed size is used as a main body of an antenna. The metal element is half wavelength or one-fourth wavelength in length, wherein the wavelength corresponds to the desired frequency band. For durability and aesthetics, a mobile device has at least a part of the housing (e.g., the front, the back or the frame/bezel) that is made of metal. However, the metal housing has a bad impact on antenna radiation.

## BRIEF SUMMARY OF THE INVENTION

In one exemplary embodiment, the subject application is directed to a mobile device, comprising: a substrate; a ground element, comprising a ground branch, wherein an edge of the ground element has a notch extending into an interior of the ground element to form a slot region, and the ground branch partially surrounds the slot region; and a radiating branch, disposed inside the slot region, and coupled to the ground branch of the ground element, wherein the ground branch and the radiating branch form an antenna structure.

## BRIEF DESCRIPTION OF DRAWINGS

The subject application can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

FIG. **1** is a diagram for illustrating a mobile device according to an embodiment of the invention;

FIG. **2** is a diagram for illustrating a mobile device according to a preferred embodiment of the invention;

FIG. **3** is a diagram for illustrating a substrate and objects thereon according to an embodiment of the invention;

FIG. **4** is a diagram for illustrating a parallel feeding element according to an embodiment of the invention;

FIG. **5** is a diagram for illustrating VSWR (Voltage Standing Wave Ratio) of the mobile device according to an embodiment of the invention;

FIG. **6**A is a vertical view for illustrating the mobile device according to an embodiment of the invention;

FIG. **6**B is a side view for illustrating the mobile device according to an embodiment of the invention;



FIG. **7**A is a diagram for illustrating the internal structure of the mobile device according to an embodiment of the invention;

FIG. **7**B is a diagram for illustrating the internal structure of the mobile device according to an embodiment of the invention; and

FIG. **7**C is a diagram for illustrating the internal structure of the mobile device according to an embodiment of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a diagram for illustrating a mobile device **100** according to an embodiment of the invention. The mobile device **100** at least comprises a substrate **110**, a ground element **120**, a radiating branch **130**, a processor, a display module, a touch-screen module, an input module, and other relative electronic components (not shown). The substrate **110** may be an FR4 substrate with a 4.3 dielectric constant. In an embodiment, the substrate **110** is approximately 0.8 mm in thickness. The ground element **120** and the radiating branch **130** are at least partially conductive. They may be made of metal, such as silver or copper, or may be coated on a carrier of the radiating branch **130** with conductive paint, such as LDS (Laser Direct Structuring). In an embodiment, the ground element **120** is a plane layer disposed on the substrate **110**.

The ground element **120** comprises a ground branch **126**. An edge of the ground element **120** has a notch **122** which extends into the interior of the ground element **120** so as to form a slot region **124**. The slot region **124** substantially has a rectangular shape. With respect to the real structure, the edge of the ground element **120** is partially open. The length W**2** of the slot region **124** is greater than the length W**1** of the notch **122**. The length W**1** of the notch **122** is approximately from 0.3 mm to 2 mm. In a preferred embodiment, the length W**1** of the notch **122** is approximately 0.6 mm. The ground branch **126** partially surrounds the slot region **124**. The radiating branch **130** is disposed on the substrate **110** or a carrier thereof. The radiating branch **130** is substantially inside the slot region **124**, and is further electrically coupled to the ground branch **126** of the ground element **120**.

The ground branch **126** and the radiating branch **130** form an antenna structure together, wherein a feeding point FP of the antenna structure may be electrically coupled to a signal source, and each of the ground branch **126** and the radiating branch **130** is a part of the current path. In a preferred embodiment, the radiating branch **130** substantially has a C-shape, and the ground branch **126** of the ground element **120** substantially has an L-shape. The length of the radiating branch **130** is greater than the length of the ground branch **126**. Note that the radiating branch **130** may be meander to form a variety of shapes, such as an L-shape or a W-shape. When an input signal is fed through the feeding point FB into the antenna structure, the radiating branch **130** is excited to form a low frequency band, and the ground branch **126** is excited to from at least a high frequency band. Therefore, the mobile device **100** can operate in multiple frequency bands.

In a preferred embodiment, the mobile device **100** further comprises a power button **150**, an FPCB (Flexible Printed Circuit Board) **155**, and a signal line **157**. The power button **150** is disposed to be close to the ground branch **126** of the ground element **120**. The signal line **157** is disposed on the FPCB **155**, and is electrically coupled between the power button **150** and the substrate **110** so as to transmit a power signal. In other embodiments, the signal line **157** may be also electrically coupled to a volume key (not shown). Note that

the signal line **157** and the FPCB **155** substantially extend along or around the ground branch **126** of the ground element **120**. Since the signal line **157** and a resonant path of the antenna structure extend in the same direction, the antenna structure is not influenced much by the power button **150** and the signal line **157**.

FIG. **2** is a diagram for illustrating a mobile device **200** according to a preferred embodiment of the invention. As shown in FIG. **2**, the mobile device **200** at least comprises a substrate **110**, a ground element **220**, and a radiating branch **130**. The mobile device **200** is similar to the mobile device **100** as shown in FIG. **1**, and relatively similar components will not be described again hereafter. Note that in the embodiment, the ground element **220** is a conductive housing of the mobile device **200**. The conductive housing has a hollow space in which the substrate **110**, the radiating branch **130** and other relative components are accommodated/disposed. Note that the conductive housing may have different shapes (e.g., the conductive housing has openings with different sizes and shapes), and the openings can be formed in any part of the conductive housing. The ground element **220** and the radiating branch **130** are at least partially conductive, and are made of metal or coated on a carrier of the ground element **220** and the radiating branch **130** with conductive paint, such as LDS.

Similarly, the ground element **220** comprises a ground branch **226**. An edge of the ground element **220** has a notch **222** which extends into the interior of the ground element **220** so as to form a slot region **224**. The ground branch **226** partially surrounds the slot region **224**. In some embodiments, the notch **222** of the ground element **220** is formed as follows: (1) from the front of the mobile device **100** to the side further to the back thereof; (2) from the side of the mobile device **100** to the back thereof; (3) from the front of the mobile device **100** to the side thereof; or (4) in one of the front, the side and the back of the mobile device **100**. In a preferred embodiment, the length W**1** of the notch **222** is approximately from 0.3 mm to 2 mm. The radiating branch **130** is disposed on the substrate **110** or a carrier thereof. The radiating branch **130** is substantially inside the slot region **224**, and is further electrically coupled to the ground branch **226** of the ground element **220**. The ground branch **226** and the radiating branch **130** form an antenna structure together, and each of the ground branch **226** and the radiating branch **130** is a part of the current path. The mobile device **200** may further comprise a parallel feeding element **270**, wherein a signal source **290** is electrically coupled through the parallel feeding element **270** to the ground branch **226** and to the radiating branch **130**, respectively. In the embodiment, since the conductive housing of the mobile device **200** is a part of the antenna structure, communication performance of the mobile device is not influenced much by the conductive housing. In addition, the ground element **220** is implemented by the conductive housing so as to save from taking up too much design space for the antennas.

In an embodiment, the mobile device **200** further comprises a power button **150**, an FPCB (Flexible Printed Circuit Board) **155**, and a signal line **157**. The ground element **220** may have a button hole **241** in which the power button **150** may be disposed. Similarly, the signal line **157** and the FPCB **155** substantially extend along the ground branch **226** of the ground element **220** (i.e., in the direction toward the notch **222**) so as to avoid interference with the antenna structure.

In an embodiment, the mobile device **200** further comprises a transparent nonconductive structure **250** and an LED (Light Emitting Diode) **260**. The transparent nonconductive structure **250** comprises at least an optical plane (not shown), and is partially embedded into the notch **222** of the ground element **220** so as to separate the ground element **220** from the open end of the ground branch **226**. The LED **260** is disposed on the substrate **110** and generates light through the transparent nonconductive structure **250**. In an embodiment, the light may blink in connection with the optical plane so as to have functions of indicating, reminding, and delivering signals. The LED **260** may be electrically coupled to a processor (not shown) of the mobile device **200**, wherein the processor is configured to control the light condition of the LED **260**.

FIG. **3** is a diagram for illustrating the substrate **110** and objects thereon according to an embodiment of the invention. As shown in FIG. **3**, the mobile device **200** further comprises a plastic carrier **310** and an antenna FPCB (Flexible Printed Circuit Board) **320**. The plastic carrier **310** is supported by the substrate **110**, and the antenna FPCB **320** is disposed on the plastic carrier **310**. The plastic carrier **310** can support the antenna FPCB **320**. In the embodiment, the radiating branch **130** is disposed on the antenna FPCB **320**, and has a variable shape. In other embodiments, the radiating branch **130** is coated on the plastic carrier **310** or other components (e.g., PCB, Printed Circuit Board) with LDS technology.

FIG. **4** is a diagram for illustrating the parallel feeding element **270** according to an embodiment of the invention. As shown in FIG. **4**, the parallel feeding element **270** comprises two connection elements **271** and **272**, wherein the connection element **271** is electrically coupled between the radiating branch **130** and the signal source **290**, and the connection element **272** is electrically coupled between the ground branch **226** and the signal source **290**. In an embodiment, the connection elements **271** and **272** are two metal springs or two pogo pins. In another embodiment, the connection element **271** is a metal trace, and the connection element **272** is a metal spring or a pogo pin. The parallel feeding element **270** is designed to use internal space of the mobile device **200** effectively.

FIG. **5** is a diagram for illustrating VSWR (Voltage Standing Wave Ratio) of the mobile device according to an embodiment of the invention, wherein the vertical axis represents VSWR, and the horizontal axis represents operating frequency (unit: MHz). As shown in FIG. **5**, the radiating branch **130** of the antenna structure is excited to generate a low frequency mode ML**1** to form a low frequency band FB**1**, and the ground branch **226** (or **126**) of the antenna structure is excited to generate at least two high frequency modes MH**1** and MH**2** to form a high frequency band FB**2**. More particularly, referring to FIG. **1**, a first current path on the ground branch **126** (from P**1** to P**2** through FP to P**3**) is excited to generate a high frequency mode MH**1**, and a second current path on the ground branch **126** (from FP to P**3**) is excited to generate another high frequency mode MH**2**. Note that the point P**1** is electrically coupled to the ground element **120**, and the position of the point P**1** is adjustable. The length of the radiating branch **130** and the length of the ground branch **226** (or **126**) may be adjusted appropriately according to desired frequency bands. In a preferred embodiment, the low frequency band FB**1** is approximately from 880 MHz to 960 MHz, and the high frequency band FB**2** is approximately from 1428 MHz to 2710 MHz. Therefore, the mobile device of the invention can cover GSM900/Band 11/GPS/DCS1800/PCS1900/UMTS bands.

FIG. **6**A is a vertical view for illustrating the mobile device **200** according to an embodiment of the invention. As shown in FIG. **6**A, the ground element **220** is a conductive housing, and the slot region of the ground element **220** substantially has a straight shape. The transparent nonconductive structure **250** is partially embedded into the notch **222** of the ground element **220**, wherein the notch **222** opens from the front of

the mobile device **200** to the side frame/bezel and further to the back. The slot region **224** can accommodate other components, such as a camera module, a light compensation module, a loudspeaker module, or a kickstand module.

FIG. **6**B is a side view for illustrating the mobile device **200** according to an embodiment of the invention. As shown in FIG. **6**B, the power button **150** is disposed in the button hole **241** of the conductive housing. The conductive housing further has an earphone hole **710** to electrically couple earphones.

FIG. **7**A is a diagram for illustrating the internal structure of the mobile device **200** according to an embodiment of the invention. As shown in FIG. **7**A, the substrate **110** may have an irregular shape. The transparent nonconductive structure **250** and the LED **260** are both connected onto the substrate **110**.

FIG. **7**B is a diagram for illustrating the internal structure of the mobile device **200** according to an embodiment of the invention. As shown in FIG. **7**B, the plastic carrier **310** may have an irregular shape, and partially cover the transparent nonconductive structure **250**. The plastic carrier **310** can support and fix objects thereon, such as the antenna FPCB **320** or the radiating branch **310**.

FIG. **7**C is a diagram for illustrating the internal structure of the mobile device **200** according to an embodiment of the invention. As shown in FIG. **7**C, the parallel feeding element **270** may comprise two metal springs **871** and **872**, wherein a signal is fed through the metal spring **871** into the radiating branch **130** (not shown), and the signal is also fed through the metal spring **872** into the ground branch **226** of the ground element **220**. In the embodiment, the metal springs **871** and **872** may have different lengths.

The subject application provides a mobile device comprising an antenna structure for operation in multiple frequency bands. A power button and a signal line of the mobile device are disposed substantially along a resonant path of the antenna structure so as to avoid interference with radiation of the antenna structure. A ground element of the mobile device is implemented by a conductive housing so as to improve communication quality of the mobile device. In addition, a parallel feeding element is designed to save from taking up too much internal space in the mobile device.

The embodiments of the disclosure are considered as exemplary only, not limitations. It will be apparent to those skilled in the art that various modifications and variations can be made in the invention. The true scope of the disclosed embodiments being indicated by the following claims and their equivalents.

What is claimed is:

**1**. A mobile device, comprising:

a substrate;

a ground element, comprising a ground branch, wherein an edge of the ground element has a notch extending into an interior of the ground element to form a slot region, and the ground branch partially surrounds the slot region;

a radiating branch, disposed inside the slot region, and coupled to the ground branch of the ground element,

wherein the ground branch and the radiating branch form an antenna structure,

wherein the mobile device further comprises:

a parallel feeding element, wherein a signal source is coupled through the parallel feeding element to a feeding point on the ground branch and to a first terminal of the radiating branch, respectively,

wherein the ground branch of the antenna structure is excited to form a first frequency band, and the radiating branch of the antenna structure is excited to form a second frequency band,

wherein a first current path from a grounded end of the ground branch through the feeding point to an open end of the ground branch is excited to generate a part of the first frequency band, and a second current path from the feeding point to the open end of the ground branch is excited to generate another part of the first frequency band, and

wherein the ground element is a conductive housing of the mobile device, and the substrate and the radiating branch are disposed in the conductive housing, and

wherein the mobile device further comprises:

a transparent nonconductive structure, partially embedded into the notch of the ground element so as to separate the ground element from an open end of the ground branch; and

an LED (Light Emitting Diode), disposed on the substrate, and generating light through the transparent nonconductive structure.

**2**. The mobile device as claimed in claim **1**, wherein a length of the slot region is greater than a length of the notch.

**3**. The mobile device as claimed in claim **1**, wherein a length of the notch is smaller than 2 mm.

**4**. The mobile device as claimed in claim **1**, wherein the slot region substantially has a rectangular shape.

**5**. The mobile device as claimed in claim **1**, wherein a length of the radiating branch is greater than a length of the ground branch.

**6**. The mobile device as claimed in claim **1**, wherein the radiating branch substantially has a C-shape.

**7**. The mobile device as claimed in claim **1**, wherein the ground branch of the ground element substantially has an L-shape.

**8**. The mobile device as claimed in claim **1**, further comprising:

a power button, close to the ground branch;

an FPCB (Flexible Printed Circuit Board); and

a signal line, disposed on the FPCB, and coupled between the power button and the substrate, wherein the signal line and the FPCB substantially extend along the ground branch.

**9**. The mobile device as claimed in claim **1**, further comprising:

a plastic carrier, supported by the substrate; and

an antenna FPCB (Flexible Printed Circuit Board), disposed on the plastic carrier, wherein the radiating branch is disposed on the antenna FPCB.

**10**. The mobile device as claimed in claim **1**, further comprising:

a plastic carrier, supported by the substrate, wherein the radiating branch is coated on the plastic carrier.

**11**. The mobile device as claimed in claim **1**, wherein the radiating branch is disposed on the substrate.

**12**. The mobile device as claimed in claim **1**, wherein the low frequency band is approximately from 880 MHz to 960 MHz.

**13**. The mobile device as claimed in claim **1**, wherein the high frequency band is approximately from 1428 MHz to 2710 MHz.

**14**. The mobile device as claimed in claim **1**, wherein the substrate has a thickness of about 0.8 mm.

**15**. The mobile device as claimed in claim **1**, wherein the radiating branch extends along a periphery of the slot region.

16. The mobile device as claimed in claim 1, wherein a second terminal of the ground branch functions as a ground point of the antenna structure.

17. The mobile device as claimed in claim 1, wherein the first connection element and the second connection element are two metal springs.

* * * * *